# Using project demand profiling to improve the effectiveness and efficiency of infrastructure projects.


## Abstract

**Purpose:** This paper explores the applicability and utility of supply chain (SC) segmentation through demand profiling to improve the effectiveness and efficiency of infrastructure projects by identifying different types of project demand profiles.

**Design/methodology/approach:** A 3-stage abductive research design was adopted. Stage 1 explored the applicability of SC segmentation, through demand profiling, to the portfolio of infrastructure projects in a utility company. Stage 2 was an iterative process of 'theory matching', to the portfolio, programme and project management literature. In stage 3, theoretical saturation was reached and 'theory suggestions' were made through four propositions.

**Findings:** Four propositions outline how SC segmentation through project demand profiling could improve the effectiveness and efficiency of infrastructure projects. P1: The ability to recognise the different demand profiles of individual projects, and groups thereof, is a portfolio management necessity. P2: Projects that contribute to the strategic upgrade of a capital asset should be considered a potential programme of inter-related repeatable projects whose delivery would benefit from economies of repetition. P3: The greater the ability to identify different demand profiles of individual/groups of projects, the greater the delivery efficiency. P4: Economies of repetition developed through efficient delivery of programmes of repeatable projects, can foster greater efficiency in the delivery of innovative projects through economies of recombination.

**Originality/value:** This work fills a gap in the portfolio management literature, suggesting that the initial screening, selection and prioritization of project proposals should be expanded to recognise not only the project type, but also each project's demand profile.



**Keywords:** Supply Chain Segmentation, Demand Profiling, Abductive Case Study, Portfolio Management, Project Profiling

## 1. Introduction

The UK construction industry has traditionally been a major contributor to the country's economic activity. In 2014 it accounted for 6.5% of the GDP, and employed more than 2 million people (Rhodes, 2015). The industry encompasses the planning, regulation, design, manufacture, construction and maintenance of buildings and infrastructure (Cox and Ireland, 2002). Public infrastructure in particular, improves the quality of life of ordinary people and the vibrancy of local communities. The UK government has set ambitious targets for the refurbishment of roads, airports, railways, and utilities infrastructure across the country for the next five years, at a cost of approximately £100 billion (UK Government, 2016). This means that there is a strong pipeline of public infrastructure projects, while the industry as a whole is projected to grow by 70% by 2025 (HM Government, 2013).

However, the construction industry suffers from low productivity compared to the manufacturing sector (Changali *et al.,* 2015). Infrastructure projects in particular, consistently overrun in terms of cost and time (e.g., Olawale and Sun, 2010). Government and consultancy reports (e.g., Egan, 1998; Latham, 1994; Wolstenholme *et al.*, 2009), as well as academic studies (e.g., Bankvall *et al.*, 2010; Hartmann and Caerteling, 2010; Ireland, 2004; Polat *et al.*, 2014), have identified similar reasons for the industry's underachievement. These include lack of demand visibility, late involvement of contractors and suppliers, design changes, adversarial relationships and lack of trust, risk transfer upstream, and reliance on a large, fragmented supply-base of Small and Medium Sized Enterprises (SMEs). The adverse effects of these factors are exacerbated by the price-driven, project nature of the industry (Gann and Salter, 2000). This often implies the creation of a new supply chain (SC) for each project, and short-term, discontinuous interfirm relationships (e.g., Briscoe and Dainty, 2005; Dainty *et al.*, 2001).

Across the various reports and studies, a salient proposed solution to the problems of the industry has been to increase SC integration (Dainty *et al.*, 2001). This recognises the important role of Supply Chain Management (SCM) in improving construction performance. The suggestion was particularly bold in Sir John Egan's pioneering report (Egan, 1998), which advocated the implementation of SCM principles that had proved successful in manufacturing. These included integrated teams and processes, long-term relationships, and a focus on continuous quality improvement. Subsequent reports and academic studies, have failed to identify substantial improvements. Many of the targets and commitments have fallen

considerably short (Wolstenholme *et al.*, 2009). It is striking to see that many of the industry's weaknesses identified in *Construction 2025* (HM Government, 2013) are clearly related to inadequate SCM, persistently discussed over the last 20 years. For example: inefficient procurement and processes, high reliance on a fragmented basis of sub-contractors (many of which are SMEs with limited access to finance), lack of collaboration and knowledge sharing from project team to project team, and so on. Despite many attempts at improvement, the industry as a whole is still underachieving, while there is increased uncertainty due to the upcoming exit of Great Britain from the European Union (BBC News, 2016).

The concept of supply chain sementation has its roots in manufacturing strategy, and builds on the concept of product-process fit initially introduced by Hayes and Wheelwright (1979). They suggest that manufacturing process choice could be linked to the product life cycle; the resultant product-process matrix recommends a diagonal path of best fit that revolutionised manufacturing strategy. There have been many restatements of this matrix. One of the most popular was developed by Slack *et al.* (1995) who reconfigured the matrix so that the axes represented volume and variety (with a scale from low to high) and the diagonal the same series of process choices from job shop to continuous flow. Fisher (1997) suggested that the concept of fit could be extended from one of product – process choice, to one of product – supply chain choice. In essence it suggested that innovative products required a *responsive* supply chain, and functional or commodity products an *efficient* supply chain. This led to the distinction between agile (responsive) and lean (efficient) supply chain responses (Christopher and Towill, 2000). At the core of supply chain segmentation is the ability to recognise and cluster the different demand characteristics of individual stock keeping units (SKUs), a process known as demand profiling (Godsell *et al.*, 2011).

Against this background, and in recognition of the huge potential of appropriately managing SCs in the construction industry, the government recently issued a related call for funded research into this[1]. In response, the authors of this study were awarded a grant, to adopt SCM insights from the Fast Moving Consumer Goods (FMCG) industry, and apply it in the context of public infrastructure construction. In particular, the proposal of the research project was to

[1] https://interact.innovateuk.org/competition-display-page/-/asset_publisher/RqEt2AKmEBhi/content/supply-chain-integration-in-construction

explore the applicability and utility of SC segmentation through demand profiling to improve the effectiveness and efficiency of construction SCs. This is also the overall aim of this paper.

The research began with the idea that infrastructure projects could be segmented according to their demand characteristics, namely, their degree of predictability and repeatability. In contrast to the common conceptualisation of projects as unique, highly customised endeavours comprising complex and non-routine activities (e.g., Gaddis, 1959; Mintzberg and McHugh, 1985) which are the 'antithesis of repetition' (Pinto, 2007), this research follows authors such as Davies and Brady (2000) and Lundin and Soderholm (1995) who argue that activities performed in a project range from unique to repetitive. It follows that projects can also be segmented into *unique* and *repetitive* (Lundin and Soderholm, 1995), or *innovative* and *routine* (Davies and Brady, 2016), based on the nature of the tasks they involve. Subsequently, different SC strategies can be followed for the different segments. This idea was explored in the context of a utility company and its infrastructure project portfolio.

The authors followed an abductive research approach (Dubois and Gadde, 2002; Kovács and Spens, 2005), iterating between theory and data, aiming to extend the theory of SC segmentation in a project context. This led the researchers to systematically combine emerging insight with established project, programme and portfolio management theory (theory matching), and empirical knowledge related to the success of the Heathrow Terminal 5 (T5) project and BAA (the former British Airports Authority BAA). The final outcome was a set of refined, contextualized theoretical propositions and a framework that, if applied, could potentially increase SC effectiveness and efficiency in the context of infrastructure construction projects.

The abductive research journey is detailed in the following section. The paper then continues with the detail of the results and analysis in Section 3. In Section 4, a summative discussion of this work is presented.

## 2. Research design

Whilst the authors believe that SC segmentation has the potential to improve the effectiveness and efficiency of construction SCs, there was a recognition that this concept alone may not fully explain the lack of SC integration (Dubois and Gadde, 2002). Thus, a 3-stage abductive research design was adopted as illustrated in Figure 1, to provide the ability to offer new insights (Kovács and Spens, 2005). Stage 1 focused on the exploration of the applicability of SC segmentation

'theory', to the 'new' context of a utility company's portfolio of infrastructure projects. Stage 2 was an iterative process of 'theory matching', to the portfolio, programme and project management literature. As the authors sought to explain the underlying mechanisms inhibiting the current performance of the project portfolio, and explore the adoption of SC segmentation in the utility infrastructure context, they compared the utility case to the success of the Heathrow T5 project, and BAA's portfolio management capability. The abductive cycle closed in step 3, when theoretical saturation was reached and 'theory suggestions' were made in the form of a conceptual framework and a set of propositions.

The specific research questions (RQs) that the study sought to address were as follows. In the context of a portfolio of projects for a utility company:

1. What is the current effectiveness and efficiency of SC processes?
2. What are the current inhibitors to greater effectiveness and efficiency of SC processes?
3. To what extent can the principles of demand profiling be applied to improve the effectiveness and efficiency of infrastructure projects?
4. How could they be applied?

Stage 1 is the predominant focus for RQs 1-3, with stages 2 and 3 dealing with the more complex 'how' of RQ4.

----------*Insert Figure 1 about here*----------

After introducing the case context in more detail (Section 2.1) the remainder of the research design follows the abductive research design process: stage 1 – prior theory applied to the new context (Section 2.2), stage 2 – theory matching (Section 2.3), and stage 3 – theory suggestions (Section 2.4).

### *2.1 Case context*

The study took the form of a single instrumental case study (Stake, 1998). Its focus was on the SC of a utility company that provides water and wastewater services, and engages with construction SCs for the improvement and maintenance of water infrastructure.

Water is a regulated industry. The Water Services Regulation Authority (WSRA) (or OFWAT as it is more commonly known), recognising the inefficiency within the water sector, sought to

improve the performance of the water infrastructure SCs by extending Asset Management Periods (AMPs) to five years. The objective was to enable the water companies to work with their partners with a longer-term view in developing their investment plans, increasing effectiveness (i.e., doing the 'right' infrastructure projects) and efficiency (i.e., executing the projects in the most efficient way).

The case-company, alongside other actors of the construction SC, created an alliance with the aim of providing the best value for money for customers. In addition to the end-client (the water company), the 'Alliance' brought together three construction firms: a design firm, a programme management partner and a technology innovation partner. Given its complexity, the 'Alliance' was operationalised through two equally sized joint ventures (JVs) and through an agreed set of principles. The water company was embedded in both JVs. This study focuses on one of the two JVs, specialised in design and construction of water infrastructure assets.

The JV adopted a strategy referred to as "Factory Thinking", aimed at creating factory levels of efficiency and "delivering customer outcomes through capital or operational interventions in the most effective, efficient, predictable and sustainable manner", as reported in an internal promotional flyer. The overarching ethos behind the formation of the JV was to replicate the success of the iconic T5 project through several principles: engagement in the whole asset life cycle, optimisation of programmes through batching, use of standard products delivered offsite, and SC integration.

Abiding by this philosophy, the JV developed a 5-year plan outlining how to address customer priorities, meet the requirements of new legislation, and provide water and wastewater services. The plan includes a portfolio of water infrastructure construction projects of different sizes. In some cases, regulatory agreements decide the exact location of the utility company's investments, and in other cases, the company has the flexibility to decide where best to make the improvements.

These principles, in their desired and actual state of application, are detailed in Section 3.1.

### *2.2 Prior theory applied in a new context*

In order to ensure the rigour of the case study design, a research protocol was developed (Easterby-Smith *et al.*, 2012). This was a living document that provided the research team and

case study partners with an overview of the rationale for the study, unit of analysis, RQs and interview schedules for the different stages.

The first step was a scoping study. As illustrated in Table 1, this involved five semi-structured interviews with members of the JV Executive Management Team (EMT). The purpose of this phase was to obtain a general understanding of the context, competitive strategy and SC of the JV. The output was a report that provided a summary of the context and a recommendation for the scope of the main study (second step). It was reviewed by members of the JV team for accuracy.

----------*Insert Table 1 about here*----------

The main study deployed a mixed-method approach. In line with Mingers and Brocklesby (1997), the reason for this was the multi-dimensional nature of the RQs, ranging from the more general and qualitative problems of effectiveness and efficiency of current SC processes, to the narrower, (quantitative) data-driven possibility of applying the principles of demand profiling.

The aim of the qualitative component of this stage was predominantly to address RQ1 and 2, and understand the current performance of SC processes and the factors inhibiting performance. It took the form of a further 13 semi-structured interviews. The interviews were conducted at two different levels of analysis: the project portfolio level – involving the senior management team (SMT) of the JV which focused on the management of the portfolio, and the project level – involving the project delivery team (PDT), which focused on the delivery of specific projects. All members of the JV SMT are employed by both end-client and main contractor; the only exception is the SC hub manager who is employed by the client.

A detailed list of the interviewees and their roles can be found in Table 1. Each interview lasted about one hour, took place in the company premises, and was recorded. The interview schedule logged the interviewee, date, time, duration and any supporting documentation. Contact notes were written within 24 hours of the interview in line with Miles and Huberman (1994). They were analysed by the authors, and the identified themes were integrated in the results of the study. The main themes were SCM practices and inhibitors of SC integration, and an initial set of variables characterising the two themes was created from the literature. For instance, SCM practices were initially characterised following the SCOR model of plan, source, make, deliver.

Two of the authors conducted an independent analysis of the interviews, identifying the quotes relevant to the two themes. Following an iterative process, each quote was related to a specific SCM practice or inhibitor, and the definitions of practices and inhibitors from the literature were integrated or tailored when needed. The results of the analysis were compared and consensus between the authors was reached.

The findings of the study were validated with members of the EMT, SMT and PDT through a 3-hour workshop in early March 2016.

The quantitative data collection and analysis took place after the validation workshop between April and August 2016. It focused on addressing RQ3 and exploring the extent to which the principles of demand profiling (accepted as being a potential solution at the validation workshop) could improve the effectiveness and efficiency of infrastructure projects. The analysis focused on the demand during the current AMP, the time period over which the JV was effective. The initial focus was on the 119 projects for which the JV was responsible. This was reduced to 110 once projects were removed because of missing data.

The data included the total cost, nature or scope (e.g., "Flood Resilience", "Process Maintenance") of projects. An appropriate, knowledgeable executive was asked to characterise each project as predictable or unpredictable, and repeatable or non-repeatable. The segmentation process and its purpose were explained to the executive through a detailed email. In response, the executive suggested some rules to facilitate segmentation, such as the introduction of cut-off points for the characterisation of the values of predictability and repeatability.

It emerged through the process that for some projects, a sub-element was largely repeatable, so an additional category of 'partially repeatable' was added. The total budget estimate and some free text comments for specific projects were also added. This information was manually analysed, and the projects were clustered based on the two dimensions.

### *2.3 Theory matching*

The theory matching process is emergent and iterative. It became apparent that whilst there was genuine potential to apply the principles of SC segmentation to the utility company context, there were a number of issues regarding the current ways of working that would inhibit this. As already mentioned, the overarching ethos of the JV was to try and replicate the benefits of the collaborative, behavioural contract of the T5 project (Brady and Davies, 2013). However, the

success of T5 did not appear to have been replicated in the context of this study, so the researchers sought to understand why. As such, they initiated contact, and organised a half-day workshop with an academic with project, programme and portfolio management expertise, who had closely studied the T5 case. Ahead of the workshop, the academic provided a number of seminal papers to provide a knowledge-base. During the workshop, the findings of this study were discussed and compared to both theory and the empirical findings from T5. The researchers then reflected on these findings, and conducted a further 1-hour Skype-based interview with the expert to further refine their understanding. This process was repeated twice until theoretical saturation was reached. From the initial workshop, the theory matching process took weeks to complete.

### *2.4 Theory suggestions*

The researchers and expert recognised theoretical saturation at the point at which consensus was reached with regard to the conceptual framework and resultant set of propositions. The framework and propositions constitute the 'theory suggestions' and the basis for further empirical work. Through theory matching and suggestions, the authors sought to address RQ4, and provide insight into how SC segmentation through demand profiling could help to improve the effectiveness and efficiency of infrastructure projects.

## 3. Analysis and results

### *3.1 Prior theory applied to a new context*

This part of the analysis seeks to provide the answers to RQs 1, 2 and 3. It thus discusses, in turn, the effectiveness and efficiency of the current SC processes, the inhibitors to greater effectiveness and efficiency, and the quantitative analysis exploring the extent to which the principles of SC segmentation through demand profiling are applicable to infrastructure projects.

#### *RQ1 – Effectiveness and Efficiency of current SC processes*

The "Factory Thinking" philosophy aims at creating factory levels of efficiency through the principles of whole asset life cycle engagement, optimisation of programmes through batching, use of standard products delivered offsite, and SC integration.

The principle of whole asset life cycle engagement implies that the construction firm expects to remain engaged with the customer following project delivery and handover. Accordingly, the construction firm is shifting from the traditional focus on Capital Expenditure (Capex) for building assets, and Operational Expenditure (Opex) to maintain these assets, to a through-life costing of initiatives (Totex). The assumption of the construction firm is that this through-life costing can achieve a 30% total cost reduction. The Head of the Water Sector of the construction firm highlighted how this Totex approach *"has implications on the way in which the business is structured, and… the way in which we set measures for people, since people have done something different for the last 20 years".* It seems that the case company faces the challenge of achieving the right fit between strategy deployment and performance metrics, like many firms from different sectors, as highlighted in a long-standing debate in the management literature (see e.g., Adams *et al.*, 1995 or Akyuz and Erkan, 2010).

Programme optimisation through batching entails a distinction between projects that have to be run as stand-alone because they share no characteristics with any other project, and projects that are almost identical to each other, for which there is value in clustering or batching. Several interviewees argued that for the proper implementation of the batching process, the key is to provide early visibility of a programme of works to the entire SC.

The product standardisation principle entails the utilisation of standard products whenever possible, so that assemblies can be designed once but installed many times. Examples of standard products are precast concrete, pumping stations, screens, tanks and scrapers. Several interviewees suggested that the innovation and standardisation of products requires early SC engagement, and design workshops at the beginning of the programmes that involve the suppliers and feasibility design teams. The introduction of standard products creates the possibility of building off-site a proportion of assets, which, according to calculations by the JV can reach 50%. Offsite delivery of assets reduces labour and time onsite, and generates returns in terms of reduced accidents and carbon emissions, and higher quality.

The JV also tried to create an integrated SC through the introduction of behavioural contracting, recognised as a critical success factor for the T5 project. Behavioural contracting was introduced by BAA in an attempt to create a new type of partnership with its suppliers. It was based on three key principles: the client always bears the risk, the partners work in integrated project teams (Davies *et al.*, 2016), and the client gives incentives to the suppliers for

positive problem-solving behaviours (OECD, 2016). In this way, BAA overcame the logic of the old Engineering and Construction Contract, that included clauses to recover money from suppliers in case of failure, and drove poor practice in construction projects. Accordingly, the JV partners tried to replicate this by agreeing to share risk among them, rather than passing it upstream to suppliers. In order to create incentives for positive problem-solving behaviours, the JV introduced a Risk, Opportunity and Innovation (ROI) fund, which was an amount of money set aside as contingency. Ideally, partners should be motivated to improve the financial performance of the project and to deposit the corresponding savings in the "risk pot", as at the end of the project, partners share the leftover money based on pre-agreed percentages.

*The actual performance of the JV:* The SC connecting the members of the JV can be represented through a modified SCOR model (Huan *et al.*, 2004), tailored to the construction context (Figure 2). The "Source" activities are replaced by the more articulated "Procurement" activities. The "Make" process becomes the sum of the "Design" and "Build" activities. The "Deliver" process is represented by the activities of "Commission and Handover". The activities covered by the "Plan" part are split into the three different levels of "Supply Chain Planning", "Project Management" and "Programme Management".

----------*Insert Figure 2 about here*----------

Programme Management deals with the planning of the 5-year programme and the encompassed projects. The head of the JV admitted that *"the actual condition is different from the ideal one"* with respect to the implementation of the principles of Factory Thinking. The programme optimisation through batching is at a very early stage, with some preliminary attempts to identify project characteristics as bases for clustering. The JV decided to split the programme into two main geographical areas with a delivery lead for each. The head of JV highlighted how the two delivery leads *"have complete accountability to translate a strategic intent into actual projects onto the ground, with end-to-end responsibility"*. Within the main geographical areas, there is a set of "quadrants" related to the nature of the project such as "Water-Infrastructure", "Water-Non-Infrastructure", "Wastewater Infrastructure", "Energy efficiency and Carbon", and so on. The criteria currently used for batching and the overall management of the programme do not include project repeatability.

Regarding the planning horizon, the JV has a 5-year business plan, but presently, due to issues with the client re-prioritising work, it has at best a 6-month view of future demand. Furthermore, it lacks the SC planning knowledge and discipline to make use of the business plan to drive a longer-term forecast, and infuse some stability into the plan. For the vast majority of the projects of the programme, the planners know the starting dates, but there is always emergent work due to emergencies or unforeseen events. The Head of the JV explained that they know roughly how much they are going to spend and *"how it will break down between design, labour, plants, materials, subcontracts"*. But uncertainty stems from the fact that the business plan was written some years ago and *"it is impossible to predict 8 years forward what your most critical problem is and what is going to be failing".* Therefore, the client repeatedly prioritises every year where to spend the money. The commercial lead observed that the JV is *"at the stage in which we have a view of what is coming in 5 years for many of the major frameworks, but the piece of work that needs to be done is to share plans with the supply-base"*. The overall inefficiency in resource usage was also confirmed by the planning lead, who gave examples of problems due to work re-prioritisation.

Project management coordinates the activities at the project level. Each project goes through a set of 'checkpoints' that cover all the activities, from the definition and design development to project implementation and handover. A project receives all the necessary approvals after the third 'checkpoint'. According to the planning lead, this leads to low resource efficiency because of *"a constant iteration of the business plans and schedules",* and because they are *"really struggling in defining any work"* before the third 'checkpoint'. The Head of Sector also highlighted how the current *"through-life project management"* is neither efficient nor effective and, *"it should start cutting away some of the iterations because design can come up with a fantastic idea but the contractor may not be able to build it"*. This also hinders early supplier involvement, which is a key tactic within the Factory Thinking strategy.

SCM activities in the JV include the coordination of purchases at the programme and project level. At the beginning of each project, a procurement schedule details the needs of individual projects, and on a monthly basis all demand plans are consolidated, providing an overall view of all forthcoming procurement expenditures. Based on this consolidated view, SC managers can select and group types of spend. The procurement manager explained that when they have those

opportunities at the programme level, they aggregate early on anything they can because it gives them savings, buying power, a view of future spend and control over financial flows.

Furthermore, while implementing the behavioural contracting principles, the risk was passed on to the suppliers through the JV contracts. In order to permit one format of contracting, each partner added all its clauses to a standard New Engineering Contract (NEC), to ensure that all requirements were met. This generated a *"monster of a contract"* that was over 70 pages long. This was then used as the basis for contracting with all the supply-base. The result has been long delays, as suppliers seek to renegotiate the unrealistic clauses. It has also caused frustration and damaged supplier trust.

Summing up, the JV is implementing the Factory Thinking Philosophy only in terms of standardisation of products and offsite construction, and is currently neglecting the other principles, related for instance to SC integration. The Head of JV thinks that *"there are some constraints that are just a step too far for people"*, but on the positive side he believes that what has been implemented is far from what the partners used to do previously, and from what normally happens in the industry.

*RQ2 – Factors inhibiting the effectiveness and efficiency of SC processes*

The interviewees referred to several inhibitors of further adoption of the Factory Thinking philosophy. The four key ones are discussed here, while a complete list is provided in Table 2.

----------*Insert Table 2 about here*----------

*Tendering culture*: The first factor inhibiting the implementation of the philosophy is the organisational culture that has been defined by the commercial lead as *"reactive to contract management"* and by the Head of JV as *"tendering based".* The reasons for this are historical; the commercial lead argued that all JV partners have a different SC focus, since, historically, they have not been involved in a multi-party contract. He continued by clearly describing how this organisational culture hinders the implementation of the desired principles. Indeed, in the current context the SC focus becomes *"getting the contract out at the cheapest price, making sure that you can get the raise as low as you can, don't pay them as quickly as possible, and then there will be another project, and there is another supply chain"*.

Similarly, the 'Alliance' SC hub manager observed that the procurement team struggles to implement the new strategy because many people *"have been doing tendering contract packages"*, while the JV is now looking for *"a strategic approach to market and out-of-the-box thinking"*. The commercial lead explained that they are currently adopting a short-term view in contradiction to the 5-year time horizon for programme optimisation. It seems particularly difficult to change this organisational culture because people with the right mentality might simply not be available in the market. One of the two delivery leads confirmed that they *"lack the procurement resources needed"*, causing delays. As the industry evolves and these approaches spread, *"there will be some people who are good at this through-life project management, and others that are less good and simply want to do the construction work"*. Moreover, the shift from the old tendering culture to the new Factory Thinking approach is difficult because of some degree of inertia to change. The SC hub manager observed that despite the plan, the necessary teams have not been built yet to make the JV fully operational. Similarly, the efficiency lead explained that the innovations, which are being introduced progressively, are mainly related to the processes for the delivery of the assets *"because a big cultural shift is involved from where they are coming from"*.

*Misunderstanding of Supply Chain Management*: "Supply Chain Management" is predominantly perceived in the JV as supply-base management. Sales and Operations Planning processes are missing, and there is an overlap between the activities of the SCM function and the procurement function. Indeed, the SC manager explained that a key difference between the two functions is that his function *"engages with the top suppliers"* rather than the less critical ones, managing the relationships with them and helping them develop.

*Low supplier integration*: The SC manager highlighted the need for *"working more closely with the suppliers"*. He mentioned the efforts of his team in making sure that suppliers are not overloaded and that the spend is not a large fraction of the overall turnover. However, he suggested that *"rather than being just suppliers"*, they should *"try to make them a part of their business"* for the proper implementation of the Factory Thinking principles. On a similar note, the SC hub manager suggested that the JV is not exploiting the *"opportunity to work with suppliers and really develop best practice solutions, sitting down and analysing together what are the options, how it is possible to add value to the particular project"*.

A cause and a consequence of the low supplier integration is the lack of trust. The SC hub manager effectively explained that this is because suppliers *"have been asked to quote for the same thing again and again, and every time that the solution changes they are asked to quote again"*. He suggested that the JV should be more open with suppliers in situations of uncertainty and ask them to *"kick around some ideas, rather than doing a lot of detailed work".* The commercial lead heavily insisted on this point, arguing that a true cultural change consists of *"demonstrating value for money and giving trust to the supply chain"* and that currently suppliers tend to distrust the contractor because of the way in which risks are passed down to the SC.

The SC hub manager highlighted that to achieve higher levels of integration, the overall number of suppliers should decrease. For example, if in the framework agreement there are seven suppliers, *"with some work these can be easily reduced to four, and the JV has better chances of winning work when it comes through".* The low integration also implies low visibility of demand for suppliers, which is very important for the Factory Thinking philosophy. The head of JV explained how they aim at creating a 5-year demand plan, with varying degrees of certainty: *"100% of confidence on what they are going to buy tomorrow, 80% confidence on what they are going to buy in the year, 60% next year and 20-30% over the 5 years".*

Another cause and consequence of low integration is the late involvement of suppliers. The Head of JV argued that in order to implement the Factory Thinking principles he would like to give to suppliers *"as much as they can as early as possible"*. However, *"when there is a more conventional procurement team, they still want terms and conditions in the contract that state that for purchase values over a threshold, they need a specific amount of quotations"*. He thinks that this is a constraint for two reasons. Firstly, a supplier in competition with six other suppliers may not want to be in that competition. Secondly, in order to obtain comparable competitive tenders from suppliers, the asset should already be designed, while in the current state the JV can only give to its suppliers *"little tangible for a competitive tender"* in terms of the design of the asset.

Such an approach is clearly in contrast with the SC integration and programme optimisation principles of the Factory Thinking philosophy. Similarly, the procurement manager indicated that *"early involvement of the procurement department would be a massive improvement"*. The reason is that if they can involve procurement in the project team decisions before going too far

in the design, the suppliers can make a contribution in these preliminary stages. The procurement manager thinks that this approach can *"drive efficiency in the design"* and *"give a much better understanding of what they are going to purchase"*. However, despite early supplier involvement being key, the procurement manager recognised how inadequate it has been so far. As the SC hub emphasised, *"a lot of knowledge and best practice ideas sit with the supply chain",* so early supplier engagement is fundamental.

*Complexity of processes*: The last major inhibitor of SC process effectiveness and efficiency is the complexity of managing an alliance of multiple partners with conflicting needs. The Head of JV explained that having a multi-partner alliance is *"exponentially more complex"* compared to traditional JVs involving 2-3 partners. Moreover, he claimed that with many stakeholders, the probability of someone not agreeing is higher, which creates *"uncertainty for everything you try to do"*. He suggested that there is a *"philosophical question about the optimal size of the JV"*. While the client perceives that *"bigger is better"* since they receive *"leverage of tens of thousands of people and lots of expertise*", the Head of JV clarified that *"the reality is that you are dealing with human beings and you have limited trust on how they are going to behave"*. The commercial lead agreed that *"having eight companies, makes it difficult to reach an agreement on what risk is acceptable"*.

Other interviewees with a project related role argued that the managerial complexity of the JV originates from the amount of required paperwork and approvals. A project director gave the example of the amount of purchases that should be approved by the Head of commercial; he explained that in the JV *"what is different is the governance, that is far more time-consuming than in a normal job"* because of *"signatures, approvals and authorisations"* that in a normal job he would do himself. He suggested that they should delegate down from the Head of commercial, so that he is not solely responsible for signing things off.

*RQ3 – Demand profiling applied to infrastructure project portfolio*

The fieldwork identified the opportunity to consider two distinct demand patterns for the water JV. Table 3 demonstrates that the vast majority are predictable and budget less than 10 million, but only 58% are fully or partially repeatable.

----------*Insert Table 3 about here*----------

### *3.2 Towards Theory Suggestions through Theory Matching*

*Theory Matching with Portfolio Management Literature*

The finding that the JV was not considering project repeatability and predictability as bases for batching, and thus not managing them accordingly, led the researchers to believe that the problem starts at the strategic level, where projects were not recognised and assigned to appropriate 'streams' to create flow. Given their SC orientation, the researchers initially identified this as a gap in the strategic planning capability of the JV. They wanted to understand why this had not appeared to be an issue for T5, and hypothesised that this may be because T5 had a more developed strategic planning capability. Following the discussions with the academic expert and the review of the available body of theoretical and empirical work (see Section 2.3), the researchers needed to explore the potential to segment the utility project portfolio based on the dimensions of predictability and repeatability, in order to achieve the 'innovation through stability'. An intermediate step, abiding by the abductive process, was to review the literature on portfolio management.

To start with, a *project* is a *"a temporary endeavour undertaken to produce a unique product, service, or result"* (PMI, 2017 p.3). The entire set of an organisation's projects can be thought to constitute the organisation's project *portfolio*. Patanakul and Milosevic (2009) argue that some of these projects may be sufficiently large, or strategic in nature, to necessitate a full-time project manager. This approach is referred to as *single-project management*. However, not all projects are large and strategic. Hence, the term *management of a group of multiple projects (MGMP)* is used to characterise the management of those smaller and more tactical projects in the portfolio that tend to be grouped and assigned to one project manager who handles them concurrently. Patanakul and Milosevic (2009) clearly state that the projects within a group are typically not mutually dependent in terms of goals. Instead, they are grouped together for the sake of efficiency and their main interdependence is that they are managed by the same project manager. This is not to be confused with *programme management*, where the constituent projects are by definition, mutually dependent, share a common goal and lead to the same deliverable. As such, programme management refers to the centralized, coordinated management of resources and activities of this group of interdependent projects, towards the defined strategic objectives and

benefits (PMI, 2017). With all these in mind, *portfolio management* refers to the management of a diverse range of projects and programmes to achieve the maximum organisational value within resource and funding constraints. The relationship between portfolio management, single project management (SPM), programme management, and MGMP is schematically presented in Figure 3, adopted directly from Patanakul and Milosevic (2009).

----------*Insert Figure 3 about here*----------

Following Blichfeldt and Eskerod (2008), portfolio management is a decision making framework that involves the:

- Initial screening, selection and prioritization of project proposals
- Concurrent re-prioritization of projects in the portfolio
- Resource allocation / reallocation between projects according to priority

As part of the initial screening, selection and prioritization one needs to be able to recognise not only the project type (Patanakul and Milosevic, 2009), but also the demand profile (e.g., predictability and repeatability) for each project. This is not something that appears to be part of the current portfolio management capability, either in literature or in practice. This was the task that the researchers asked the JV Managing Estimator to complete, the results of which were presented in Table 3. This suggests that the 95% of projects which were characterised as predictable should be able to be planned over the 5-year duration, and not to be subject to major reprioritization. This critical activity helps inform the prioritisation of projects in the portfolio and avoid unnecessary re-prioritisation which can be hugely disruptive for the efficiency of the SC. Because SCs are subject to the bullwhip effect (Lee *et al.*, 1997), changes in the prioritisation of the portfolio that may have a relatively small impact at the portfolio management level, have an increasing impact in terms of demand predictability as they ripple through the tiers of the SC. In addition, this creates distrust, requires costly buffers against uncertainty and is a significant contributor to the inefficiency of construction SCs. The ability to profile the demand is a strategic part of the demand planning capability (Godsell *et al.*, 2011) long recognised by the O&SCM community. It is a capability that could be 'borrowed' (Whetten *et al.*, 2009) to enhance the current portfolio management capability. This leads to the first proposition:

**P1:** ***The ability to recognise the different demand profiles of individual projects, and groups thereof, is a portfolio management necessity.***

Segmenting individual projects (or groups thereof) according to their demand profiles suggests that there may be different ways to manage repeatable versus non-repeatable projects.

*Repeatable projects as a new type of programme*

Sir John Egan (1998) recognised the importance of utilising manufacturing principles in the construction context. Indeed, within this study context, the philosophy of Factory Thinking was a cornerstone upon which the JV was built. One of the issues in the implementation of the encompassed principles was the fact that the JV had limited their understanding and effort to the concept of off-site assembly. Furthermore, they could not identify opportunities to implement the other principles due to the constant re-prioritisation of the project portfolio by the client in the short term planning horizon (0-3 months). Deceptively, this made projects appear both unpredictable and non-repeatable. The concepts of repeatability and predictability are commonly applied in the FMCG context (Godsell *et al.*, 2011). The construction industry, which is a project-based environment, is somewhat different since both the frequency (intermittence) and size (lumpiness) of the projects are more variable than in Fast Moving Consumer Goods (FMCG). Syntetos *et al.* (2005) have developed an approach for categorising demand patterns based on the intermittence (frequency of demand) and lumpiness (size of the demand when it occurs). For the purposes of this study, major projects with a value greater than £10 million could be considered as creating 'lumpy' demand. It is evident that the different project groupings as identified by Patanakul and Milosevic (2009) have different demand profiles. For instance, as illustrated in Table 4, SPM typically consist of large projects (i.e., high lumpiness) that occur only once (i.e., low intermittence). These projects often tackle a unique issue, which is why they are not repeatable. They can be *innovative* because *"they explore innovative alternatives, experiment with new ideas, schemes and approaches, and create entirely new technologies and markets"* (Davies and Brady, 2016 p.319). In contrast, they could also be *routine* projects if they *"exploit the existing base, utilise proven technologies and mature products, and address current customer demands"* (Davies and Brady, 2016 p.319). Given their size, and irrespective of whether they are innovative or routine in nature, these projects are usually not emergent and can be planned. 3% of the sample fit the SPM category.

----------*Insert Table 4 about here*----------

MPM is typically used when there is a series of one-off (i.e., low intermittence), small projects (i.e., low lumpiness) that cannot justify a dedicated project manager and are managed as a group of small unrelated projects. In the study context, 35% of projects fell into this category. These types of projects would tend to be *routine* in nature. Traditional programme management involves the management of a set of projects that are linked to the delivery of a strategic goal. Within the programme, the individual projects tend to be discrete (i.e., low intermittence) but could vary in size (i.e., low/high lumpiness) and the type of solution (e.g., routine/innovative).

----------*Insert Figure 4 about here*----------

As illustrated in Figure 4, this research has identified an additional type of programme management – that of a set of repeatable projects. They are a programme, as they have a strategic objective (e.g., to provide the upgrade of a particular type of asset) but differ from traditional programme management in that within the programme the projects are necessarily routine (and repeatable). Thus they could be planned in such a way as to provide the stability through which the SC can improve efficiency. Such projects will benefit from 'economies of repetition' (Davies and Brady, 2000) whereby the supplying organisation can deliver a series of similar projects at lower cost and more effectively, taking advantage of the learning opportunities that this offers. This leads to the second proposition:

***P2: Projects that contribute to the strategic upgrade of a capital asset, should be considered a potential programme of inter-related repeatable projects whose delivery would benefit from 'economies of repetition'.***

It also became evident that there is a link between the effectiveness of the portfolio management capability to be able to distinguish between different demand profiles for groups of projects, and the efficiency of execution in project delivery.

*Effectiveness of portfolio management and efficiency in project delivery*

Moving towards saturation through 'theory matching', it became clear that effectiveness and efficiency in the construction industry operate at different levels of analysis. The critical area 'to do the right thing' is at the portfolio management level, where frequent re-prioritisation of projects sends shockwaves down the SC and leads to inefficiencies. The critical missing portfolio management capability, as identified in P1, is the strategic planning capability required to identify the different demand profiles of individual projects and groups thereof. In this context, the possible benefits associated with the management of 45% of projects as sets of repeatable projects, could provide a bedrock of stability from which the end-to-end SC can drive efficiency by 'doing things right'. A predictable and repeatable demand pattern enables the removal of costly buffers of uncertainty, and reduces the time required for processing and expediting. Consequently, it fosters the collective adoption of 'lean' SC principles, driving productivity at an SC rather than the individual company level. This can be summarised in:

***P3: The greater the ability to identify different demand profiles of individual and groups of projects, the greater the efficiency of delivery.***

There is a further advantage from this approach. One of the key learnings from BAA under the stewardship of Sir John Egan, was that the group benefitted from the 'economies of repetition' of routine projects. At the time of T5, BAA operated across a number of airports, and what appeared to be a routine task at one (e.g., resurfacing a runway) had to be repeated, either at the same or other airports. BAA proactively used these types of projects to drive efficiency into their processes. The learning they derived from this routine work, executed from a paradigm of repetition (i.e., programme of repeatable projects) not only led to improvements in their capability to deliver similar routine projects, but also enabled them to leverage their capability to deliver large scale, one-off, innovative projects (e.g., T5) more efficiently. In other words, leveraging the 'economies of repetition' developed through routine projects facilitated efficient delivery of innovative projects through 'economies of recombination' (Grabher, 2004). Namely, the T5 project team were able to reuse and place their project knowledge into 'modules' that were components (or elements of sub-projects) of the overall T5 project. Furthermore, BAA was able to harness its routine projects to experiment with new ways of doing things in a less risky environment than in a major project such as T5. In this way they were able to 'validate' the new ways of doing things before embarking on T5. This study also found that 11% of projects were partially repeatable, i.e., not repeatable in their entirety but an element (or module) within them

is. This was in addition to the 45% of fully repeatable projects. This leads to the final proposition:

***P4: Economies of repetition developed through efficient delivery of programmes of repeatable projects, can foster greater efficiency in the delivery of innovative projects through economies of recombination.***

## 4. Discussion and conclusions

The four propositions describe how the principles of SC segmentation through demand profiling could be applied to improve the effectiveness and efficiency of infrastructure projects**.**

This has been an informative piece of research from three perspectives: the utility of abductive research, contribution to theory, and potential to create a step change in practice.

*Utility of abductive research*

The abductive approach provided the authors with a legitimate means to explore the mechanisms through which the principles of SC segmentation could be applied to a portfolio of infrastructure projects. In seeking to understand the mechanisms by which SC segmentation could be embedded within the infrastructure project context, it was necessary to iterate between the empirical findings of the study, and portfolio, programme and project management literature. Through this process, not only was a new academic union made, but new theory was built after conflicting but equally valid bodies of literature were brought together. A potential gap in the portfolio management literature was identified, one where the initial screening, selection and prioritization of project proposals (Blichfeldt and Eskerod, 2008) should be expanded to recognise not only the project type (Patanakul and Milosevic, 2009), but also the demand profile (e.g., predictability and repeatability) for each project (Godsell *et al.*, 2011). Addressing this gap could be a crucial missing link in improving the effectiveness of portfolio management to enable the more efficient execution of projects. Only further empirical work will be able to test this, but the foundations are firmly laid here.

*Contribution to theory*

The major contribution to theory stems from the idea that every project is not totally unique, but it has elements within it that are replicated in other projects. These could include the design,

materials, components, equipment, implementation plans, commissioning processes and so on. The identification of these elements and the grouping of projects on the basis of them is called 'project demand profiling'. The abductive research process is a powerful approach for theory building. The iteration between the empirical findings of the potential of segmentation through demand profiling, and the explanatory power of the portfolio management literature, has enabled four propositions to be developed. These provide a platform, which other scholars in the field can seek to test and extend. In addition to the proposition that strategic portfolio planning is a missing part of the portfolio management capability, this paper has provided insight on how the concept of SC segmentation can extend the work of Davies and Brady (2000). It illustrates how 'economies of repetition' (for repeatable projects) could enable 'economies of recombination' for both large and non-repeatable, 'innovative' projects. This has been made possible by extending Patanakul and Milosevic's (2009) multi-project environment to include the programme management of repetitive projects (PMRP).

*Potential to create a step change in practice*

The power of abductive research is that it helps to create a theoretically grounded vision of how practice can be changed. It helps to address the concerns of Wickham Skinner that research in O&SCM is largely incremental in nature[2]. The framework and associated propositions provide a clear platform from which to engage an industry that has been struggling for almost three decades with the inefficiencies caused by poor SC integration. It is exciting to think that this research can play a part in reversing this trend. The rigorous way in which the framework and propositions have been developed provide an easy way to engage practitioners in conversation. Indeed, one company has already agreed to empirically test the ideas developed here.

Moreover, and as a side-contribution, the following 5-step process can be adopted (and modified, as needed) by practitioners, particularly in the construction industry as shown, to help them apply the ideas of segmentation in their project portfolio.

*Step 1: Programme identification*. This step aims at identifying a programme for the segmentation analysis. The programme should be big enough to make the segmentation exercise

[2] A concern raised in his keynote address at the 2010 Decision Science Institute (DSI) Annual Conference, San Diego

meaningful. From the results of the study, the authors suggest that the programme should involve at least 100 projects.

*Step 2: Segmentation criteria setting*. This step defines the criteria used for the identification of the project demand segments and the strategy used for their measurement. Although different criteria can be potentially applied, the results of the study suggest the adoption of three criteria:

- Project Repeatability. A measure of whether the projects of a specific type generally follow the same design, use the same (or similar) materials, resources and equipment, and are implemented according to a similar plan. Project repeatability can be expressed in percentages. The estimator can set a cut-off point that characterises the project as non-repeatable, partially repeatable, or repeatable. For instance, the estimator can decide that a project is partially repeatable if its repeatability is higher than 50% and repeatable if its repeatability is higher than 70%.

- Project Predictability. A measure of whether the projects are planned well in advance with a high degree of certainty, versus being scheduled on an *ad hoc* basis. The estimator can set a cut-off point that characterises the project as predictable or not predictable. For instance, the estimator can decide that a project is predictable if it has been planned one year before its start date.

- Budget. It measures the budget allocated to the project, and cut-off points should be based on the individual history and context of the particular organisation.

*Step 3: Data collection*. The data needed for the assessment of the criteria is collected. This step is not trivial because the data can imply the screening of different sources and it may involve the *ad hoc* generation of some of the data (e.g., the measure of repeatability).

*Step 4: Project assessment*. All the projects are assessed based on the criteria.

*Step 5: Data analysis*. The data is analysed and the demand segments are identified, as discussed at the end of Section 3.1.

From a pedagogical perspective, the idea that projects are not all totally unique, and that project demand profiling can improve the efficiency and effectiveness of projects, can help O&SCM students when conceiving, grouping and executing their projects. Just to mention an example, project demand profiling will allow future leaders to adopt in the project management environment more and more tools originally developed in the manufacturing environment.

Another key contribution of this study consists in providing a rigorous example of application of prior theory to a new context. Learners can replicate the methodology of the study for the application of theories in new contexts, and they can also use the study as benchmark for the assessment of the validity of their results. Moreover, the contribution to knowledge highlighted in the previous paragraphs is particualry relevant from a pedagogical perspective because the propositions are combined with a simple stepwise procedure that allow learners to observe the complex inteplay between theory and practice.

*4.3 Limitations and further research*

As with any case study research, this work is limited as to its generalisability; the insights may not apply to other utility infrastructure companies. Indeed, other companies may have adopted and internalised the lessons from T5 more effectively and holistically. Nevertheless, the newly identified role of project demand profiling as a portfolio management capability, pertaining to the managing of groups of repeatable projects, is an idea that needs to be further explored in the utility infrastructure or other construction environments. A possible application of the identified concepts and principles will validate them empirically, and potentially solidify them theoretically. Another limitation of this work is its sole focus on strategic SC planning as a performance-enhancing mechanism in construction. Further research could investigate other industries, as well as empirically examine how these principles trickle down to the day-to-day project operations, and how they affect project performance in conjunction with other factors. Finally, one should be cognisant of the fact that we have provided just one approach for segmenting projects (i.e., based on their demand profiles). There may be many other ways to do this that could be more or less useful, depending on the nature of the industry, organisation or project portfolio.

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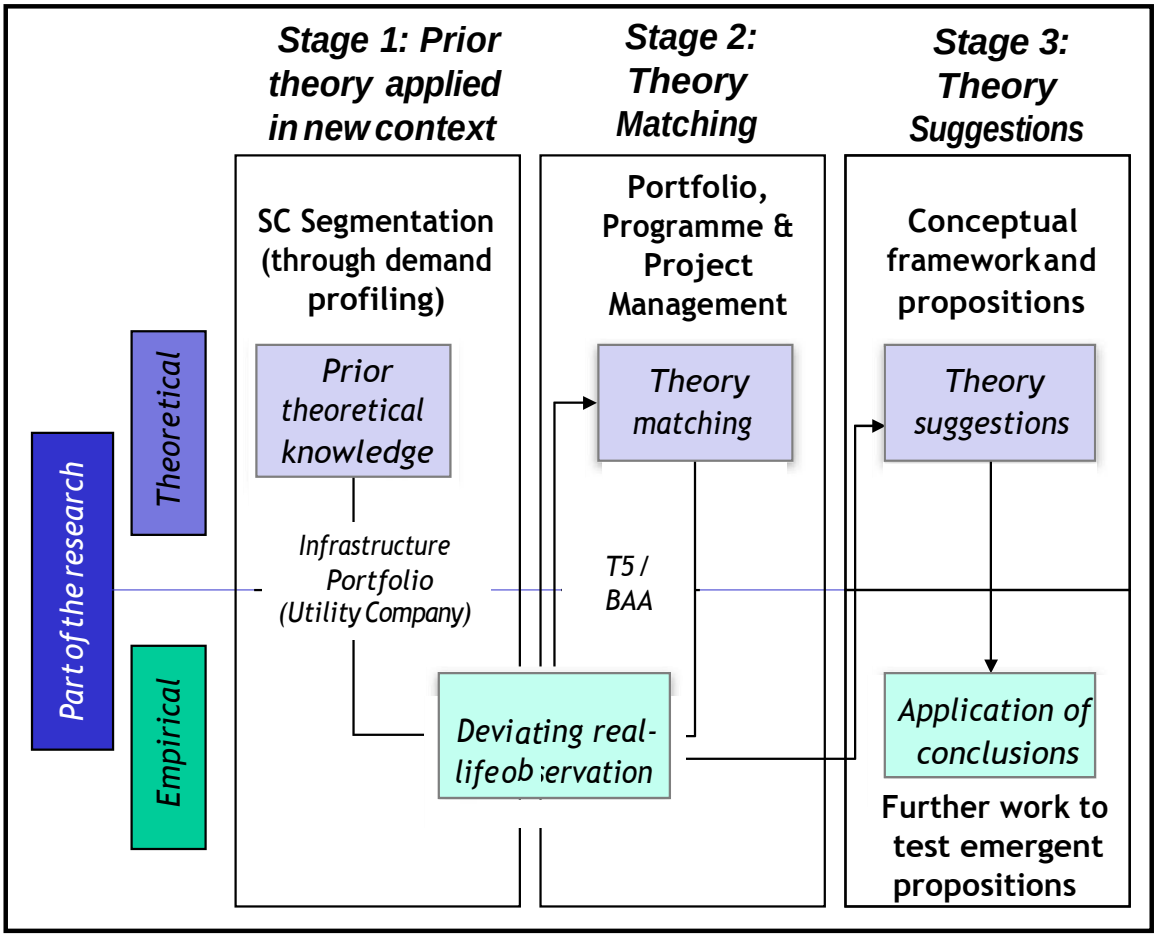


Figure 1 - The 3-stage abductive research design process (after Kovács and Spens, 2005)

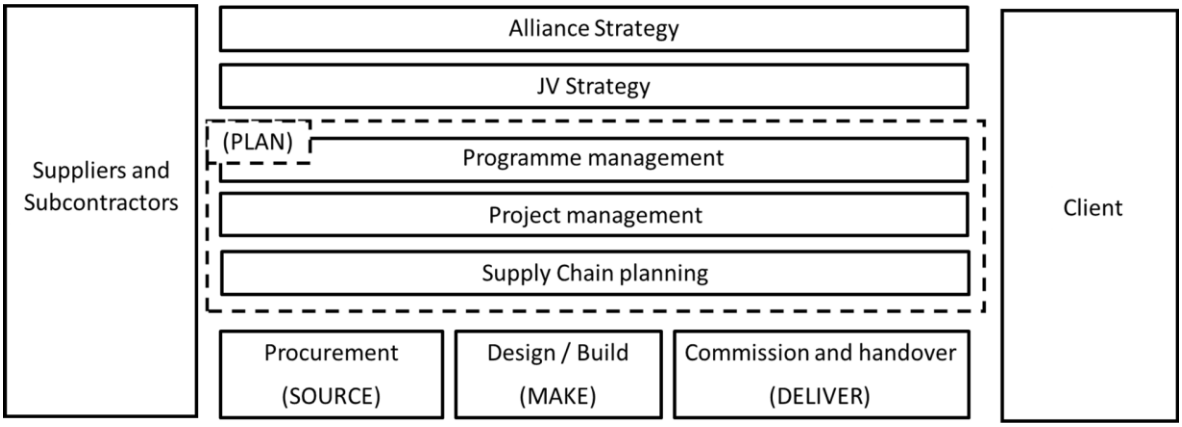


Figure 2 – Modified SCOR model for the construction sector

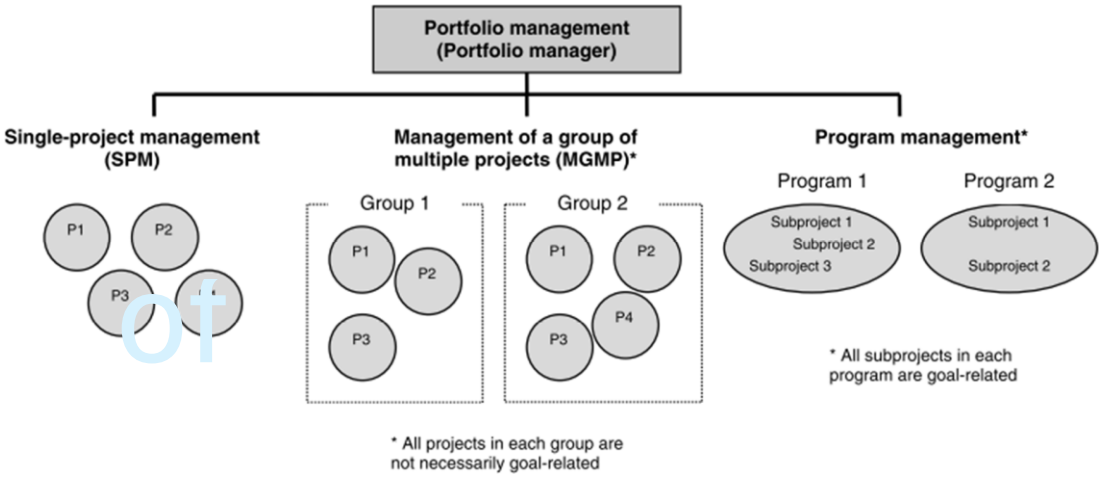


Figure 3 – A multi-project environment (Patanakul and Milosevic, 2009)

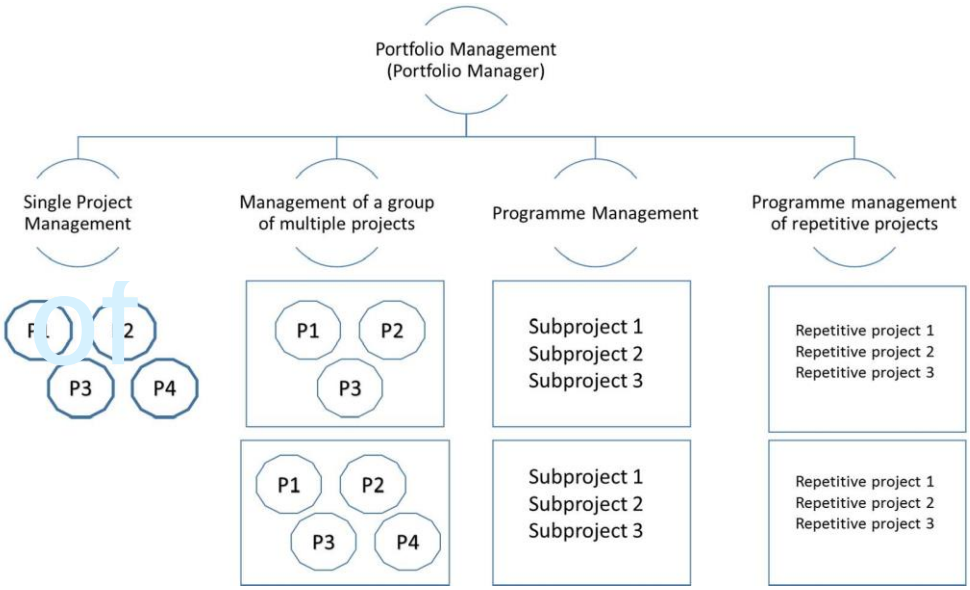


Figure 4 – A revised framework of a multi-project environment

Table 1 – Interviewees for the two stages of the study

| **Project Stage** | **Level of Analysis** | **Interviewee's Role** |
|---|---|---|
| Stage 1: Scoping Study | Executive Management Team (EMT) | Head of Sector |
| | | Head of JV |
| | | Planning manager |
| | | Supply chain Manager |
| | | Delivery lead |
| Stage 2: Main Study | Senior Management Team (SMT) | Commercial lead |
| | | Efficiency lead |
| | | MEICA lead |
| | | Production manager |
| | | HSE lead |
| | | Project director |
| | | Project director |
| | | Procurement manager |
| | | Supply Chain Manager (alliance) |
| | | Alliance SC hub manager |
| | Project Delivery Team (PDT) | Project manager |
| | | Planner |
| | | Mechanical, Electrical, Instrumentation, Control & Automation (MEICA) lead engineer |

Table 2 – Current inhibitors of SC effectiveness and efficiency

| Interviewee / Inhibitor | Head of sector | Head of JV | Planning manager | Sector SC manager | Delivery lead | Efficiency lead | Commercial head | MEICA lead | Production manager | HSE lead | Project director | Project director | Procurement manager | Alliance SC manager | Project manager | Planner | MEICA lead engineer | Alliance SC hub |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tendering culture** | X | X | X | X | | X | | | | | X | | | X | | | | X |
| **Misunderstanding of SCM** | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| **Low supplier integration** | | X | X | X | X | X | X | | | X | | X | X | X | | | | X |
| **Complexity of processes** | X | X | | | | | X | | | | | X | X | | X | X | | X |
| **Low use of standard design** | | | | | | | | | | | | | X | | | | | X |
| **Lack of effective ICT** | | | X | | | | | | X | | | | X | | | | | |
| **Poor incentives for suppliers** | | | | | X | X | X | | | | | | | | | | | X |
| **Wrong contractual clauses** | | X | | X | X | X | X | | | | | | | X | | | | X |

Table 3 – Project repeatability, predictability and size

| Major Projects / Projects | Non Repeatable | Partially Repeatable | Repeatable |
|---|---|---|---|
| **Not Predictable** | 0<br>5(5%) | 0<br>0(0%) | 0<br>2(2%) |
| **Predictable** | 3(3%)<br>39(35%) | 3(3%)<br>9(8%) | 4(4%)<br>45(41%) |

Notes
1. Major Project > £10,000,000 (lumpy demand) and Projects < £10,000,000 (non-lumpy demand)
2. Number of projects (total = 110) reported and percentage in parenthesis

Table 4 – Different demand profiles for different types of project grouping, and types of projects within the groupings

| **Type of Project Grouping (after Patanakul and Milosevic, 2009)** | **Type of projects within grouping (after Brady and Davis, 2016)** | **Type of demand profile of projects within grouping (after Syntetos et al., 2005)** | **Percentage of 110 projects in JV (not excluded 11% partially repeatable projects)** |
|---|---|---|---|
| Single Project (Management) | Routine / Innovative | Low intermittence – high lumpiness | 3% |
| Multiple Project (Management) | Routine | Low intermittence – Low lumpiness | 35% |
| Traditional Programme (Management) | Routine / Innovative | Low Intermittence – Low / High lumpiness | NA – study was of a portfolio of projects |
| *Programme Management of Repetitive Projects* | *Routine* | *High intermittence – Low / High Lumpiness* | 4% + 41% = 45% |